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EFFECT OF QUALITY OF CHEST RADIOGRAPHS ON THE CATEGORIZATION OF COALWORKERS' PNEUMOCONIOSIS

BY

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From the Pneumoconiosis Field Research of the National Coal Board

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An investigation into the effect of variations in radiographic technical quality on pneumoconiosis reading standards in the Pneumoconiosis Field Research of the National Coal Board is reported. From the group of men for whom retake films had been obtained because of unsatisfactory technique of the originals, a trial series of pairs and triplets of films showing differing technique was assembled.

A total of 778 films was read for pneumoconiosis and assessed for technical quality by four readers. The quality was assessed in terms of three separate factors, *viz.*, density (at high, medium, and low levels), contrast (satisfactory and unsatisfactory), and definition (satisfactory and unsatisfactory). The intra and inter observer consistency of this assessment was estimated, and the effect of techical quality on the reading of pneumoconiosis category was determined. A tendency for lower pneumoconiosis readings to be recorded on films with unsatisfactory technique was demonstrated.

A random 10% sample of the best available films (those on which routine pneumoconiosis readings have been made) for all men examined since the beginning of the research was also read for technical quality. Of the total of 4,188 films, 80% were considered satisfactory. It appeared that films taken on second surveys were, in general, of rather better quality than those taken on first surveys.

The physical attributes of the men examined had some effect on the technical standards, the proportion of unsatisfactory films rising with increasing values of the weight/sitting height ratio and being greater in men with pneumoconiosis categories 1 and A and in the middle age group.

The tendency for lower pneumoconiosis readings to be recorded on films with unsatisfactory technique is in contrast to the results of work previously published. Different criteria for the selection of films and the assessment of technical quality, and possibly differing reading conventions, make comparisons with other work difficult.

The generally accepted method of diagnosis and categorization of pneumoconiosis in life is by means of a chest radiograph. The appearance of such a radiograph for any given subject depends on the many complex factors associated with taking and processing the film. The subsequent categorization of pneumoconiosis is based on a subjective interpretation of the radiograph, and this interpretation may well be affected by the technical quality of the film.

Experienced readers have long been aware of this problem, and investigations to date have produced conflicting results. Fletcher and Oldham (1949) showed that radiographic technique may have a seriously disturbing effect on classification. They found that soft (under-exposed) films were generally considered to show more disease than hard (over-exposed) films of the same case taken on the same day, although some observers were less affected than others by these factors. Moreover, in an attempt to provide some absolute measure of technique differences, they compared the average change of opinion on their films with the change in densitometer readings in the third right anterior rib space.

Only a very rough linear relationship between the two was found and they concluded that 'while optical density is one factor which results in change of opinion with changes in radiographic technique, other factors are probably involved'. On the other hand, Liddell (1961) found that film quality, assessed in all cases by a numerical acceptability score, and in some cases in terms of greyness or blackness, introduced only slight biases into the reading of pneumoconiosis. Although on average the readers tended to over-correct for technical faults (*i.e.*, to read more abnormality in black films than in good ones and less in grey), some readers under-corrected slightly. A clear tendency was found for the assessment of the quality of the film to depend on the subject, men with no radiological evidence of pneumoconiosis tending to produce films assessed as of better quality than those with pneumoconiosis. Among the latter, chest thickness had an important effect on the film quality, men with thicker chests producing poorer films. Wise and Oldham (1963) found that in a series of chest radiographs of South Wales coal-face workers, simple pneumoconiosis categories 0 and 3 were read proportionately more often on acceptable than on imperfect films. Imperfect quality in this case was assessed in terms of whiteness, greyness, and blackness, and the black films were found to have more than twice as much effect on readings as grey and white films.

Cochrane and Thomas (1964), using this same classification, stated that whereas some years ago Cochrane 'over-read white films and under-read black films', an analysis by Wise and Oldham (1963) of his more recent readings showed the bias mentioned above towards differential placing of unacceptable films into pneumoconiosis categories 1 and 2. Cochrane and Thomas (1964) further showed that still more recently readings obtained by another observer (W. G. Clarke) demonstrated once more the original bias of over-reading white and under-reading grey films.

With the exception of Fletcher and Oldham's (1949) soft and hard assessment, and Liddell's (1961) numerical acceptability score, all previous workers have used classifications based on degrees of whiteness, greyness, and blackness, corresponding presumably to varying degrees of overall film density.

Despite the inconsistency of these workers' results, a similar system of classification into acceptable and grey, black, and other faults (at acceptable and unacceptable levels) was applied to a batch of films by two of the readers in the Pneumoconiosis Field Research of the National Coal Board (P.F.R.). Their experience was unfavourable, mainly because it was subject to a quite unacceptable level of intra and inter observer error, and also on general grounds, in the sense that the system was non-specific.

Acceptability scoring alone, although useful for assessing the overall quality in film series, is unsatisfactory in that it cannot be used to study the effects of particular dimensions of film quality. Fletcher and Oldham's (1949) finding that factors other than optical density are probably involved in the effect of film quality on reading standards is in accord with the writers' experience that frequently films of similar overall density and degree of abnormality (as judged by other acceptable films for the same subjects) may present quite differing degrees of difficulty in categorization. It also seemed to us that the important factors in producing this variation were:

(*a*) Density—the amount of silver deposited on the film in the area of the lung fields, and therefore a measure of the translucency of the radiographic image;

(*b*) Contrast—the differentiation in light-transmitting properties of the respective silver deposits constituting the radiographic image; and

(*c*) Definition—the distinctness of the image of specific lung structures and abnormalities.

Although these dimensions (density, contrast, and definition) cannot be considered to be truly independent (very high or low density levels will, for instance, affect both contrast range and definition), we consider that their contributions to film quality can in practice be separately assessed. Extreme degrees of technical fault, where the individual contribution admittedly cannot be judged, occur only in those films which are frankly unreadable.

These same three quality factors are discussed and listed as distinct major 'faults in radiographs' by Longmore (1955) who also considers them to be caused by largely independent factors in the taking and processing of radiographs.

A fundamental aspect of the P.F.R. (Fay and Rae, 1959) is the assessment of the prevalence and progression of radiological pneumoconiosis (Rae, Ashford, Morgan, Pasqual, and Pearson, 1963). In spite of great care being given to the standardization of methods, it has not been possible to eliminate variations in technical quality from film to film either within a survey or from one survey to another. In order to assess the significance of the readings obtained, it is necessary to determine whether the classification of pneumoconiosis is affected by these variations in technique, and, if so, to what extent.

This paper gives an account of the studies which have been made into this aspect of film reading in the P.F.R. It describes the selection of a trial film series and the elaboration and use of a classification to investigate the effect of technique on *x*-ray reading standards. It also refers to work carried out to assess

variations of technical quality in the main body of survey films, and the influence of individual physical characteristics of subjects on radiographic technique.

Selection of Films

It was decided to obtain the trial series from the group of films for which, because of unsatisfactory technique of the originals, retake films had been obtained. The intervals between taking the original and replicate films did not exceed one month (and in the majority of cases were much less), and it may be assumed that there will have been no significant change in the degree of pneumoconiosis during that time.

The alternative approach of obtaining similar material by deliberately taking replicate films, with controlled variations in technique, was rejected on ethical grounds.

Following an examination of all the films obtained since the beginning of the research, a series of 778 films was assembled, the basis of selection being that there should be two or more films of differing technique available for the same man on the same survey, and that there should be some suggestion of radiological abnormality on at least one of the films. The series included all possible pairs or triplets of films fulfilling these criteria.

The films were independently read in a random order on two separate occasions, for both *x*-ray category and radiographic technique, by each of the four readers engaged in the P.F.R.

It is later shown that technical faults are, in the main, randomly distributed and attributable to errors in the taking and processing of films rather than to differences from subject to subject. Moreover the average distribution of abnormality based on the four pairs of duplicate readings was as follows:

Category	%
0	57·0
1	27·4
2	10·5
3	1·1
A	3·0
B	1·0

It is therefore considered justifiable to draw general conclusions from the results obtained from this film series.

Classification of Radiographic Technique

There is no established system for the assessment of radiographic technique. Methods used by other workers in this field were considered and rejected as unsuitable for our purpose for reasons given in the introduction. The four readers taking part in this present study considered that the range of appearances of chest radiographs depend mainly on variations of the three factors already defined. If categorization is affected by film quality it would be an advantage to be able to assess the individual contribution of these parameters.

A classification was evolved whereby density was divided on a subjective basis into three levels, high, medium, and low, and contrast and definition each into two levels, satisfactory and unsatisfactory. The possibility of making objective assessments of density and contrast by densitometry was considered but had to be rejected as it was found impossible to obtain a satisfactory single index that described appropriately the overall appearance of both lung fields. The range of variation of technical quality is therefore divided into three (independent) dimensions and embraces 12 distinct classes.

Results

Consistency of the Assessment of Technique.—Before such a subjective classification could be applied to the main results of the research, it was necessary to find whether the four readers could use it in a uniform way.

The intra-observer error associated with the system may be measured in terms of the consistency of the duplicate readings by the same observer. Details are given in Tables 1 and 2 which compare respectively the results obtained by readers A and C on their two sets of readings. When the complete 12-way classification is considered the percentage of consistent readings varied from 64·3% for A to 82·2% for C. When each of the factors is considered separately, the consistency achieved was of the order of 80% to 90% for almost all the comparisons. Readers B and D achieved an intermediate level of consistency, and their results (which are omitted in the interests of space) show a similar pattern. In general, the average standards applied by the same observer on his first and second readings were in good agreement.

A measure of the inter-observer error may be obtained by comparing the first readings of each of the six possible pairings of the four readers. As examples, Tables 3 and 4 show the comparisons AC and CD and, as might be expected on general grounds, the agreement is rather less close than that obtained between the first and second readings by the same observer. Taking all six comparisons, for the complete 12-way classification the level of consistency varies from 40% to 65%, and the corresponding figures for the individual factors lie between 60% and 85%.

TABLE 1

COMPARISON OF DUPLICATE READINGS FOR TECHNIQUE BY READER A (NO. OF FILMS)

First Reading

	Density	Con.	Def.	High Satis. S	High Satis. US	High Unsatis. S	High Unsatis. US	Medium Satis. S	Medium Satis. US	Medium Unsatis. S	Medium Unsatis. US	Low Satis. S	Low Satis. US	Low Unsatis. S	Low Unsatis. US	
Second Reading	High	S	S	24	0	2	0	8	1	0	0	0	0	0	0	
			US	7	4	4	2	3	1	0	0	0	0	0	0	
		US	S	5	0	3	1	2	1	1	1	1	0	0	0	
			US	2	2	2	3	1	0	0	0	0	0	0	0	
	Medium	S	S	13	1	2	0	303	30	5	1	11	0	2	0	
			US	3	0	0	0	43	72	0	1	2	3	1	1	
		US	S	1	0	0	1	6	3	7	4	2	1	2	1	
			US	0	0	0	0	1	2	0	3	0	0	0	1	
	Low	S	S	0	0	0	0	4	1	0	0	21	2	3	1	% of consistency
			US	0	0	0	0	1	4	0	1	9	9	1	3	
		US	S	0	0	0	0	1	1	0	0	14	1	14	5	
			US	1	0	0	0	2	3	0	2	7	7	13	37	64·3

Density (regardless of Contrast and Definition)

First Reading

	Density	High	Medium	Low	Total	
Second Reading	High	61	19	1	81	
	Medium	21	481	27	529	% of consistency
	Low	1	20	147	168	
	Total	83	520	175	778	88·6

Contrast (regardless of Density and Definition)

First Reading

	Contrast	Satisfactory	Unsatisfactory	Total	
Second Reading	Satisfactory	580	30	610	% of consistency
	Unsatisfactory	67	101	168	
	Total	647	131	778	87·5

Definition (regardless of Density and Contrast)

First Reading

	Definition	Satisfactory	Unsatisfactory	Total	
Second Reading	Satisfactory	457	57	514	% of consistency
	Unsatisfactory	103	161	264	
	Total	560	218	778	79·4

Bearing in mind the difficulties associated with a subjective assessment of this kind, a comparison of the results obtained on the different sets of readings indicates that the standards adopted by the four readers are in reasonable agreement and that the system of classification is a reproducible one. The readings of technical quality obtained in the trial appear to provide an acceptable basis for the study of the effect of technique on the classification of pneumoconiosis.

Film Quality and X-Ray Category.—The effect of technique on the classification of pneumoconiosis may be assessed by comparing the readings on the corresponding duplicate films of the trial series. Because of the comparatively small amount of material available for study it did not prove possible to work in terms of the complete 12-way classification of radiographic technique. Instead, the three 'dimensions' of technique were considered separately, and for each a comparison was made of the pneumoconiosis categories assigned on all available pairs of films. Details of representative results are given in Tables 5 to 8, which refer respectively to the first and second readings by readers B and D. These show that there is a tendency for lower pneumoconiosis readings to be recorded on films with unsatisfactory contrast or definition. Reference to the numbers of entries above and below the diagonals in Tables 5a, 6a, 7a, and 8a shows the effect with regard to contrast, and Tables 5b, 6b, 7b, and 8b demonstrate a similar effect for definition.

There are three levels of density, high, medium, and low, and Tables 5c, 6c, 7c, and 8c (which are con-

TABLE 2

COMPARISON OF DUPLICATE READINGS FOR TECHNIQUE BY READER C (NO. OF FILMS)

First Reading

	Density	Con.	Def.	High Satis. S	High Satis. US	High Unsatis. S	High Unsatis. US	Medium Satis. S	Medium Satis. US	Medium Unsatis. S	Medium Unsatis. US	Low Satis. S	Low Satis. US	Low Unsatis. S	Low Unsatis. US	
Second Reading	High	S	S	85	2	3	0	10	0	0	0	0	0	0	0	
			US	1	8	0	0	0	2	0	0	0	0	0	0	
		US	S	2	0	16	3	0	0	1	0	0	0	0	0	
			US	0	1	0	13	0	0	0	0	0	0	0	0	
	Medium	S	S	8	0	0	0	272	3	7	1	3	0	0	0	
			US	1	1	0	0	9	36	0	1	1	2	0	0	
		US	S	1	0	1	0	5	0	16	3	3	0	0	0	
			US	0	0	0	1	0	1	1	8	0	0	0	1	
	Low	S	S	0	0	0	0	10	0	3	2	103	5	6	1	% of consistency
			US	0	0	0	0	1	1	0	0	5	19	0	3	
		US	S	0	0	0	0	0	0	1	0	7	0	14	4	
			US	0	0	0	0	0	0	0	0	1	3	6	49	82·2

Density (regardless of Contrast and Definition)

First Reading

	Density	High	Medium	Low	Total	
Second Reading	High	134	13	0	147	
	Medium	13	363	10	386	% of consistency
	Low	0	18	226	244	
	Total	147	394	236	777	93·1

Contrast (regardless of Density and Definition)

First Reading

	Contrast	Satisfactory	Unsatisfactory	Total	
Second Reading	Satisfactory	588	27	615	% of consistency
	Unsatisfactory	24	138	162	
	Total	612	165	777	93·4

Definition (regardless of Density and Contrast)

First Reading

	Definition	Satisfactory	Unsatisfactory	Total	
Second Reading	Satisfactory	577	24	601	% of consistency
	Unsatisfactory	26	150	176	
	Total	603	174	777	93·6

cerned with this dimension of technique) therefore appear in three parts, corresponding to the comparisons between high and medium, high and low, and medium and low density. These show that there is a tendency for the pneumoconiosis readings on the medium density films to be higher than on either the corresponding high or low density films.

First and second readings by all four observers show similar trends, with a tendency for lower pneumoconiosis readings to be made on the films with unsatisfactory definition and contrast, and high and low density, in comparison with the corresponding satisfactory definition and contrast, and medium density films. Most of the differences recorded on the individual readings are statistically significant, and when all the results are taken together the tendency is very highly significant.

Although there were too few films to carry out any general examination of the complete 12-way classification, the following three subdivisions each contained up to about 50 pairs of films on the individual sets of readings: (i) satisfactory contrast and definition with high and medium density, (ii) satisfactory contrast and definition with medium and low density, and (iii) satisfactory contrast and medium density with satisfactory and unsatisfactory definition. The readings on these restricted groups of films show the same trends as the larger, more heterogeneous groups considered in the main analysis. It is therefore considered most unlikely that any possible interactions between the three dimensions of the quality assessment could have accounted for the observed results.

TABLE 3

COMPARISON OF READINGS FOR TECHNIQUE BY READERS A AND C (FIRST READINGS—NO. OF FILMS)

Reader C

Reader A	Density	Con.	Def.	High Satis. S	High Satis. US	High Unsatis. S	High Unsatis. US	Medium Satis. S	Medium Satis. US	Medium Unsatis. S	Medium Unsatis. US	Low Satis. S	Low Satis. US	Low Unsatis. S	Low Unsatis. US	
	High	S	S	31	1	12	3	5	0	2	1	0	0	0	0	
			US	1	1	1	3	0	0	0	1	0	0	0	0	
		US	S	2	0	2	5	2	0	2	0	0	0	0	0	
			US	1	1	0	3	0	0	1	1	0	0	0	0	
	Medium	S	S	57	4	3	2	233	10	12	2	43	3	3	3	
			US	6	5	2	0	54	30	3	3	11	3	1	1	
		US	S	0	0	0	0	4	0	3	2	3	0	1	0	
			US	0	0	0	0	2	1	3	3	2	1	1	0	
	Low	S	S	0	0	0	1	6	1	2	1	39	3	6	8	% of consistency
			US	0	0	0	0	0	1	0	0	7	11	0	4	
		US	S	0	0	0	0	1	0	1	1	8	3	8	14	
			US	0	0	0	0	0	0	0	0	10	5	6	28	50·5

Density (regardless of Contrast and Definition)

Reader C

Reader A	Density	High	Medium	Low	Total	
	High	67	15	0	82	
	Medium	79	365	76	520	% of consistency
	Low	1	14	160	175	
	Total	147	394	236	777	76·2

Contrast (regardless of Density and Definition)

Reader C

Reader A	Contrast	Satisfactory	Unsatisfactory	Total	
	Satisfactory	566	80	646	% of consistency
	Unsatisfactory	46	85	131	
	Total	612	165	777	83·8

Definition (regardless of Density and Contrast)

Reader C

Reader A	Definition	Satisfactory	Unsatisfactory	Total	
	Satisfactory	491	68	559	% of consistency
	Unsatisfactory	112	106	218	
	Total	603	174	777	76·8

Technical Quality of Existing Survey Films and Effect of Physical Characteristics of Subjects on Technical Standards.—A random 10% sample of best available films (those on which routine pneumoconiosis readings have been made) for all men examined since the beginning of the research was also read for technical quality. It is of interest that, of the total of 4,188 films in this sample, 80% were considered to be satisfactory. This work confirmed that the standards of assessment are reproducible. It also showed that, although in general second survey films were of better quality than those taken on the first surveys, considerable variations exist in standards, both between collieries and between surveys at the same colliery.

At collieries where two surveys had been completed the sample consisted of 10% of those men present at both surveys, and by choosing the same men for both the first and second surveys it was possible to investigate the effect of individual physical characteristics of subjects on the radiographic technique.

The percentage of men with satisfactory films on both the first and second surveys is shown in Table 9. When all three aspects of technique are taken into account, the individual colliery proportions vary between 56% and 97%, with a mean of about 66%. If technical defects were entirely random and independent of personal characteristics, the expected proportion of men with satisfactory films on both the first and second surveys would equal the product of the proportions of satisfactory films on each separate survey. If, however, personal factors were entirely responsible for technical defects the propor-

TABLE 4

COMPARISON OF READINGS FOR TECHNIQUE BY READERS C AND D (FIRST READINGS—NO. OF FILMS)

Reader C

	Density	Density		High				Medium				Low				
		Con.		Satis.		Unsatis.		Satis.		Unsatis.		Satis.		Unsatis.		
		Con.	Def.	S	US	S	US	S	US	S	US	S	US	S	US	
Reader D	High	S	S	78	3	7	1	30	1	4	0	1	0	0	0	
			US	4	5	1	1	4	3	0	0	0	0	0	0	
		US	S	7	0	6	0	2	0	2	2	0	0	0	0	
			US	6	3	6	14	1	1	3	2	0	0	0	0	
	Medium	S	S	3	0	0	0	224	14	7	2	17	1	0	0	
			US	0	1	0	0	12	18	0	2	0	2	0	0	
		US	S	0	0	0	0	3	0	3	1	0	0	0	0	
			US	0	0	0	1	0	2	1	3	0	0	0	0	
	Low	S	S	0	0	0	0	26	2	4	0	81	7	5	5	% of consistency
			US	0	0	0	0	3	1	0	0	11	13	1	3	
		US	S	0	0	0	0	0	0	3	1	7	0	10	5	
			US	0	0	0	0	2	1	2	2	6	6	10	45	64·4

Density (regardless of Contrast and Definition)

Reader C

	Density	High	Medium	Low	Total	
Reader D	High	142	55	1	198	
	Medium	5	292	20	317	% of consistency
	Low	0	47	215	262	
	Total	147	394	236	777	83·5

Contrast (regardless of Density and Definition)

Reader C

	Contrast	Satisfactory	Unsatisfactory	Total	
Reader D	Satisfactory	565	43	608	% of consistency
	Unsatisfactory	47	122	169	
	Total	612	165	777	88·4

Definition (regardless of Density and Contrast)

Reader C

	Definition	Satisfactory	Unsatisfactory	Total	
Reader D	Satisfactory	530	45	575	% of consistency
	Unsatisfactory	73	129	202	
	Total	603	174	777	84·8

tion of men with satisfactory films on both surveys would be the same as the corresponding figures for each of the surveys separately. In the event, the observed proportion (65·9%) of men with completely satisfactory films on both surveys is slightly greater than the product (78·4 × 82·4 = 64·6%) of separate survey proportions. Moreover, results for individual collieries all show a similar trend. This indicates that the personal factors of the subjects have some effect on technical standards. When the three aspects of the technique assessment were considered separately it was found that the greatest departure from the hypothesis of independence occurred for definition and the least for contrast. The small size of the difference between observed and expected values does however suggest that the majority of the faults are randomly distributed and can thereby be attributed to the taking and processing of the films rather than to differences from subject to subject.

As a further test of whether or not unsatisfactory technique is randomly distributed, the proportions of men with satisfactory films on first and second surveys were subdivided in terms of *x*-ray category, age, respiratory symptoms, ventilatory function, and physique.

The tabulations of the results in terms of age, presence or absence of respiratory symptoms complex (Rogan, Ashford, Chapman, Duffield, Fay, and Rae, 1961), ventilatory function, and physique have not been included. However, they can be summarized as follows.

The proportion of men with completely satisfactory films on the first survey increases from 84%

TABLE 5

EFFECT OF TECHNIQUE ON *X*-RAY CATEGORY: READER B's FIRST READINGS (NO. OF PAIRS OF FILMS)

(*a*) *Contrast*

		Satisfactory								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Unsatisfactory	0	58	16	2		1				77
	1	3	18	1		1				23
	2		1	5						6
	3									
	A					4				4
	B									
	C									
	D									
	Total	61	35	8		6				110

$\chi^2 = 11{\cdot}56$; $P < 0{\cdot}001$

(*b*) *Definition*

		Satisfactory								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Unsatisfactory	0	63	19	2		1				85
	1	9	17	5						31
	2		3	3	1					7
	3					1				1
	A	1				6	1			8
	B									
	C									
	D									
	Total	73	39	10	1	8	1			132

$\chi^2 = 6{\cdot}72$; $P < 0{\cdot}01$

(*c*) *Density*

		High								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Medium	0	22	2			1				25
	1	9	6	1						16
	2	1	4	3						8
	3									
	A		1			1				2
	B									
	C									
	D									
	Total	32	13	4		2				57

$\chi^2 = 6{\cdot}37$; $P < 0{\cdot}05$

		High								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Low	0									
	1		1							1
	2		1	1						2
	3									
	A									
	B									
	C									
	D									
	Total		2	1						3

$\chi^2 = 1{\cdot}00$ N.S.

TABLE 5 (*cont.*)

		Medium								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Low	0	72	16							88
	1	6	18	2						26
	2	1	2	7	1					11
	3				1					1
	A					3	1			4
	B									
	C									
	D									
	Total	79	36	9	2	3	1			130

$\chi^2 = 4{\cdot}17$; $P < 0{\cdot}05$

TABLE 6

EFFECT OF TECHNIQUE ON *X*-RAY CATEGORY: READER B's SECOND READINGS (NO. OF PAIRS OF FILMS)

(*a*) *Contrast*

		Satisfactory								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Unsatisfactory	0	42	11							53
	1	5	18	4						27
	2		2	2						4
	3									
	A					4				4
	B									
	C									
	D									
	Total	47	31	6		4				88

$\chi^2 = 2{\cdot}91$ N.S.

(*b*) *Definition*

		Satisfactory								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Unsatisfactory	0	59	11	2		1				73
	1	10	20	2		1				33
	2		3	1						4
	3					1				1
	A		1			4				5
	B									
	C									
	D									
	Total	69	35	5		7				116

$\chi^2 = 0{\cdot}50$ N.S.

(*c*) *Density*

		High								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Medium	0	28	1			1				30
	1	5	11							16
	2		5	3		1				9
	3		1		1					2
	A	2				3				5
	B									
	C									
	D									
	Total	35	18	3	1	5				62

$\chi^2 = 6{\cdot}25$; $P < 0{\cdot}05$

(*cont.*)

TABLE 6 (*cont.*)

		High								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Low	0									
	1		2							2
	2		2	1						3
	3									
	A									
	B									
	C									
	D									
	Total		4	1						5

$\chi^2 = 2{\cdot}00$ N.S.

		Medium								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Low	0	69	12							81
	1	8	18	4		1				31
	2		2	7						9
	3									
	A					7	1			8
	B									
	C									
	D									
	Total	77	32	11		8	1			129

$\chi^2 = 2{\cdot}29$ N.S.

TABLE 7

EFFECT OF TECHNIQUE ON *X*-RAY CATEGORY: READER D's FIRST READINGS (NO. OF PAIRS OF FILMS)

(*a*) *Contrast*

		Satisfactory								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Unsatis-factory	0	57	27	2		1				87
	1	6	13	19	1		1			40
	2		4	8	1					13
	3									
	A					1				1
	B					1	1			2
	C									
	D									
	Total	63	44	29	2	3	2			143

$\chi^2 = 26{\cdot}68$; $P < 0{\cdot}001$

(*b*) *Definition*

		Satisfactory								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Unsatis-factory	0	54	23	3		3				83
	1	5	10	15		2				32
	2		3	11						14
	3				1					1
	A						1			1
	B					1	1			2
	C									
	D									
	Total	59	36	29	1	6	2			133

$\chi^2 = 25{\cdot}79$; $P < 0{\cdot}001$

TABLE 7 (*cont.*)

(*c*) *Density*

		High								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Medium	0	36	2							38
	1	16	20	2						38
	2	2	12	13		1				28
	3		1	1	1					3
	A	2	2							4
	B					1	2			3
	C									
	D									
	Total	56	37	16	1	2	2			114

$\chi^2 = 24{\cdot}38$; $P < 0{\cdot}001$

		High								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Low	0	13	7							20
	1	2	3	1						6
	2		5	5		1				11
	3			1						1
	A									
	B									
	C									
	D									
	Total	15	15	7		1				38

$\chi^2 = 0{\cdot}06$ N.S.

		Medium								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Low	0	65	11	3						79
	1	9	16	4						29
	2		3	5						8
	3				1					1
	A		1			4				5
	B									
	C									
	D									
	Total	74	31	12	1	4				122

$\chi^2 = 0{\cdot}81$ N.S.

TABLE 8

EFFECT OF TECHNIQUE ON *X*-RAY CATEGORY: READER D's SECOND READINGS (NO. OF PAIRS OF FILMS)

(*a*) *Contrast*

		Satisfactory								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Unsatis-factory	0	56	18	7						81
	1	12	15	18						45
	2			9						9
	3									
	A	1		1		1				3
	B					1	3			4
	C									
	D									
	Total	69	33	35		2	3			142

$\chi^2 = 13{\cdot}53$; $P < 0{\cdot}001$

(*cont.*)

TABLE 8 (*cont.*)

(*b*) *Definition*

	Satisfactory								
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Unsatisfactory	0	63	23	6						92
	1	8	16	16		2				42
	2		1	12						13
	3					1				1
	A					1	1			2
	B					1	3			4
	C									
	D									
	Total	71	40	34		5	4			154

$\chi^2 = 25{\cdot}78$; $P < 0{\cdot}001$

(*c*) *Density*

	High									
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Medium	0	34	2			1				37
	1	18	14	1						33
	2	1	13	18						32
	3			2		1				3
	A	1	3			2				6
	B						2			2
	C									
	D									
	Total	54	32	21		4	2			113

$\chi^2 = 25{\cdot}33$; $P < 0{\cdot}001$

	High									
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Low	0	16	5	1						22
	1	3	4	2						9
	2	1	3	4		1				9
	3			1						1
	A	1								1
	B									
	C									
	D									
	Total	21	12	8		1				42

$\chi^2 = 0{\cdot}0$ N.S.

	Medium									
	X-Ray Category	0	1	2	3	A	B	C	D	Total
Low	0	68	15	1						84
	1	6	15	6						27
	2	1	1	3						5
	3				1					1
	A			1		1				2
	B									
	C									
	D									
	Total	75	31	11	1	1				119

$\chi^2 = 5{\cdot}45$; $P < 0{\cdot}05$

TABLE 9

PERCENTAGE OF MEN WHOSE FILMS WERE ASSESSED AS SATISFACTORY FOR TECHNIQUE ON BOTH FIRST AND SECOND SURVEYS

No. of Men	Density	Contrast	Definition	All Aspects
1,700	79·9	86·0	89·9	65·9

TABLE 10

PERCENTAGE OF TOTAL SAMPLE OF FILMS ASSESSED AS SATISFACTORY FOR TECHNIQUE IN TERMS OF *X*-RAY CATEGORY (ALL COLLIERIES FOR WHICH DEFINITIVE READINGS ARE AVAILABLE)

X-Ray Category	Technique				
	No. of Films	Density	Contrast	Definition	All Aspects
0	2,417	87·3	92·2	94·3	78·6
1	332	88·6	86·7	88·9	71·7
2	149	89·3	93·3	96·0	81·9
3	44	86·4	88·6	100·0	81·8
A	60	86·7	95·0	86·7	73·3
B C D	26	92·3	92·3	88·5	80·8
All	3,028	87·5	91·7	93·7	78·0

for the under 21 years age group, to 88% for 21 to 25 years, then falls fairly steadily with age to 71% for 56 to 60 years, but rises again to 78% for 61 to 65 years, and 90% for over 65 years. A similar trend is apparent for density and contrast separately, but the proportion of films with satisfactory definition shows a much smaller variation with age. The results for the films obtained on the second surveys exhibit much the same pattern.

Data concerning ventilatory function, respiratory symptoms, and physique were examined for six collieries. The results show no association between radiographic technique and ventilatory function or respiratory symptoms when due account is taken of age, physique, and pneumoconiosis.

There is however a general tendency for the proportion of unsatisfactory films to rise with increasing values of the weight/sitting height ratio, *i.e.*, with increasing fatness of the subject. This trend holds good for density, contrast, and definition alike.

Discussion and Conclusions

It was known from the beginning of the Pneumoconiosis Field Research that unsatisfactory radiographic technique might introduce error into the categorization of pneumoconiosis, and great efforts were made to ensure the highest possible standards of film quality (Fay and Rae, 1959). Even so, when during the second-round surveys readers were faced with the problems of deciding whether serial films of the same man showed progression of simple pneumo-

coniosis, the difficulties introduced by variations in radiographic technique were such that it was apparent that their effect on reading standards in the P.F.R. would have to be investigated.

The results show that, despite the inherent difficulties associated with the subjective assessment used, the standards adopted by the four readers are in reasonable agreement and the system of classification is reproducible.

They also demonstrate a consistent relationship between radiographic technique, as defined, and pneumoconiosis readings. All four readers show a tendency to read less abnormality on films that are not technically satisfactory, and this is true for each separate dimension of film quality.

It is also shown that, although bad technique seems mainly to depend on the way in which films are taken and processed, it does bear a definite relation to some personal attributes of the subject; unsatisfactory films tend to occur more frequently among *x*-ray categories 1 and A than among other categories of simple and complicated pneumoconiosis, more frequently among middle-aged than younger and older age groups, and more frequently among fatter than thinner men.

These relationships are difficult to explain. Although assessment of quality was made without conscious reference to the category of pneumoconiosis, it is nevertheless possible that the diagnostic problems associated with reading categories 1 and A exerted an effect on the readers. The poorer quality among middle age groups is to be expected, but the improvement in the older age groups is puzzling. It is also perhaps surprising that ventilatory function and respiratory symptoms showed no consistent relationship with film quality. The deterioration of all dimensions of quality with an increasing weight/sitting height ratio is consistent with the results of Liddell (1961).

On the basis of this study, it is not possible to measure the effect of bad technique on a single film or on the films of a complete colliery population. On general grounds it seems reasonable to assume that the influence will be progressive; the worse the particular fault, the greater the effect on reading standards.

Many of the films included in the series for the study had been rejected on survey and 'retake' films had been obtained. The quality of unsatisfactory films and the associated lowering of *x*-ray category in this trial series are therefore likely to be worse than in the films on which survey readings are based. Because of the inherent difficulties of reading, it is improbable that further refinements of the technique classification would enable quantification of this difference (between 'trial' and 'routine survey' films) to be made. As far as the results obtained on the first round of surveys are concerned, it seems unlikely that differences in radiographic technique from colliery to colliery will have had any appreciable effect on the reported prevalence of pneumoconiosis or on the correlation studies. Only a small proportion of the 20% of men with unsatisfactory films will have been sufficiently near to a category boundary for their definitive readings to have been altered. However, the changes in abnormality levels under consideration in progression studies may well be so small that differences in technique become important. In the circumstances, the only opportunity to investigate their effect will occur when correlations between progression of pneumoconiosis and environmental exposure are carried out.

If, to this end, the results of correlation studies for men with satisfactory and unsatisfactory films are treated separately, due account must be taken of the observed association of technical quality with age, pneumoconiosis category, and physique.

It would seem advisable to make an assessment of technique (in the terms described above) on all films so far taken during routine medical surveys, and to continue the practice in future surveys.

During the present study, this system of classification was applied without conscious reference to the degree of abnormality. It was the common experience of the readers that some of the films assessed as technically imperfect could nevertheless be read for pneumoconiosis without loss of confidence. Since such films might unnecessarily be excluded from dosage/response correlations for satisfactory films, it was decided to make a further study. The effect of technique is now being investigated in terms of an additional (to the system already described) single assessment as to whether or not quality is such that a film can be read for pneumoconiosis category without loss of confidence. In making such a judgment there does of course lie the implication that the readers are able to pre-judge the effects of technique on reading standards. The results of the completed study will be reported in due course.

The results described in this paper differ from those of previous studies. These inconsistencies could be entirely due to the adoption by the readers in other studies of different 'conventions' for reading technically unsatisfactory films. As might be deduced from our results, when decisions on categorization of poor quality films have to be taken, it is our practice to read pneumoconiosis only when sure that specific opacities are present, and when doubt exists as to the profusion of specific opacities, to assign the lower reading. Moreover, as the films used in other studies were selected and assessed by different criteria, it is

not possible to draw conclusions about the relative performances of readers.

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